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(54) **OPERATION OF DROPLET DEPOSITION APPARATUS**

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Description

[0001] The present invention relates to methods of operating pulsed droplet deposition apparatus, in particular an inkjet printhead, comprising an array of parallel channels disposed side-by-side, a series of nozzles which communicate respectively with said channels for ejection of droplets therefrom; connection means for connecting the channels with a source of droplet fluid; and electrically actuable means for ejecting a droplet from a selected channel.

[0002] Such apparatus is known, for example, from WO95/25011, US-A-5 227 813 and EP-A-0 422 870 and in which the channels are separated one from the next by side walls which extend in the lengthwise direction of the channels and which can be displaced in response to the actuating signal. The electrically actuable means typically comprise piezoelectric material in at least some of the side walls.

[0003] The last of the aforementioned documents discloses the concept of "multipulse greyscale printing": firing a variable number of ink droplets from a single channel within a short period of time, the droplets merging (in flight and/or on the paper) to form a correspondingly variable size printed dot on the paper. Figure 1 is taken from the aforementioned EP-A-0 422 870 and illustrates diagrammatically droplet ejection from ten neighbouring printhead channels ejecting varying numbers (64,60,55,40,etc.) of droplets. The regular spacing of successive droplets ejected from any one channel indicates that the ejection velocity of successive droplets is constant. It will also be noted that this spacing is the same for channels ejecting a high number of droplets as for channels ejecting a low number of droplets.

[0004] In the course of experiment, several deviations from the behaviour described in EP-A-0 422 870 have been discovered.

[0005] The first finding is that the first droplet to be ejected from a given channel is slowed by air resistance and may find itself hit from behind by subsequently ejected droplets travelling in its slipstream and therefore subject to less air drag. First and subsequent droplets may then merge to form a single, large drop.

[0006] The second finding is that the velocity of such a single, large drop will vary depending on the <u>total</u> number of droplets ejected in one go from a given channel. This is not a desirable condition: as is generally known, variation in drop velocity leads to dot placement errors.

[0007] A third finding relates to three-cycle operation of the printhead - described, for example in EP-A-0 376 532 - in which successive channels in a printhead are alternately assigned to one of three groups. Each group is enabled in turn, with enabled channels ejecting one or more droplets in accordance with incoming print data as described above. It has been discovered that the velocity of the single, large drop formed by the merging of such droplets will vary depending on whether the adjacent channel in the same group is also being operated (i.e. 1 in 3 channels) or whether only the next-but-one channel in the same group is being operated (i.e. 1 in 6 channels).

[0008] These findings are illustrated in Figure 2 which shows the velocity U of the first drop to hit the paper (which may be a single droplet or a large drop made up of several merged droplets) against the total duration T of a draw-reinforce-release (DRR) actuating waveform. Such a waveform - well known in the art - is illustrated in figure 3a and places a printhead channel initially in an expanded condition (a "draw" as at E), subsequently switches to a contracted condition (a "reinforce" as at RF) and then "releases" (as at RL) the channel back to its original condition. As shown in figure 3a, the draw and reinforce periods of the waveform used to obtain figure 2 are equal and have a peak-to-peak amplitude of 40V (this need not necessarily be the case, however). Each repetition of the waveform results in the ejection of one droplet and, as shown in figure 3b, the waveform may be repeated several times in immediate succession so as to eject several droplets ("droplets per dot" or "dpd") and form a correspondingly sized dot on the paper. It will be appreciated that this step is repeated for each channel every time the group to which it belongs is enabled and the incoming print data is such that it is required to print a dot. In the experiment used to obtain the data shown in figure 2, channels were repeatedly enabled - and dots were printed - at a frequency of 60Hz.

[0009] It will be seen that the application of a single DRR waveform of around 4.5 μs duration (to eject a single droplet i.e. 1 dpd) will result in a velocity of approximately to 12m/s per second if only alternate channels in a group are fired (1 in 6 operation) whereas a velocity of around 14 m/s results if every channel in a group is fired (1 in 3 operation). The velocity is that measured shortly before the drop hits the paper and after any merging has taken place. However, applying the same waveform seven times in immediate succession (7 dpd) so as to eject seven droplets results in a velocity of around 37 m/s when operated "1 in 3" and a velocity of around 25 m/s when operated "1 in 6".

[0010] Such wide variations in velocity could give rise to significant dot placement errors. The present invention has as an objective the avoidance of such dot placement errors when generated by the newly-discovered phenomenon described above.

[0011] Accordingly, the present invention consists in a method according to claim 1, an inkjet printhead according to claim 25, and a drive circuit according to claim 26.

[0012] In the method of operating the inkjet printhead for printing on a substrate, the printhead has an array of channels;

a series of nozzles which communicate respectively with said channels for ejection of droplets therefrom;

connection means for connecting the channels

with a source of ink;

and electrically actuable means associated with each channel and actuable a plurality of times in accordance with print tone data, thereby to eject a corresponding number of droplets to form a printed dot of appropriate tone on the substrate;

the method being characterised by the steps of:

applying a one or a plurality of electrical signals to the electrically actuable means associated with a channel in accordance with the print tone data, either the duration of each signal or, where each signal is held at a given non-zero level for a period, the duration of the period being selected such that the velocity of the droplet ejected from said nozzle in response to said signal is substantially independent of (a) whether or not the electrically actuable means of the channels in the vicinity of said channel are similarly actuated to effect drop ejection simultaneously with drop ejection from said nozzle, and (b) the number of droplets to be ejected in accordance with the print tone data.

[0013] Preferred embodiments of the invention are set out in the dependent claims and description. The invention also comprises droplet deposition apparatus and drive circuit means adapted to operate according to these claims.

[0014] Thus, in accordance with the claims, it has been discovered that there are certain advantageous values of total waveform duration T at which the aforementioned variation in velocity is much reduced. In the case of Fig. 2, it will be seen that by operating a printhead with a waveform of approx. 3.8 μs duration, the velocity remains fairly constant at around 12 m/s regardless of the number of droplets ejected in one go or the firing/non-firing status of adjacent channels in the same group. Similarly, operation with a waveform of around 7.5 μs or greater will result in a fairly constant velocity although, at only 4 m/s, this is less desirable.

[0015] Figure 2 was obtained using a printhead of the kind disclosed in the aforementioned WO95/25011 and having a ratio (L/c) of closed channel length to velocity of pressure waves in the ink of approximately 2 μs. As is known from WO97/18952, for example, such a ratio corresponds approximately to the time taken for a pressure wave in the ink to travel the closed channel length i.e. half the period of oscillation of longitudinal pressure waves in the channel. This is reflected in the "1 in 3/1 dpd" trace which has a resonant peak at that value of T (=4μs) at which the compression and expansion elements of the actuation waveform are each of 2μs duration. Thus, expressed in terms of L/c, the advantageous values referred to above are 1.9L/c and > 3.75L/c respectively.

[0016] It should be noted that at 2μs, this duration is significantly shorter than is employed in similar printheads designed to eject a single ink droplet in any one droplet ejection period - so-called "binary" printing - in which a greater channel length L is required to achieve the necessary greater droplet volume. The corresponding reduction in maximum droplet ejection frequency is offset by the fact that only one - rather than a plurality - of drops need be ejected to form the printed dot on the substrate. In contrast, "multipulse greyscale" operation - in which a plurality of droplets form the printed dot - typically requires a printhead in which the half period of oscillation of longitudinal pressure waves in the channel has a value not exceeding 5 μs, preferably not exceeding 2.5 μs, in order that sufficiently high repetition frequencies and, secondarily, sufficiently low droplet volumes can be achieved.

[0017] Whilst the aforementioned advantageous values of waveform duration will vary with printhead design, actuation waveform and dot printing frequency, the manner in which they are determined - namely from a graph of the kind shown in figure 2 - will remain the same. For various values of actuation waveform duration T, velocity data U is obtained either from analysis of the landing positions of ejected droplets on a substrate moving at a known speed or - preferably - by observation of droplet ejection stroboscopically under a microscope.

[0018] Figure 4 shows data obtained for another printhead of the kind discussed in WO95/25011 with L/c again equal to 2μs and actuation with the 40V peak-to-peak DRR waveform of figure 3a. The figure shows not only the extremes of 1 and 7 dpd operation but also the intermediate values of 2,3,4,5 and 6 dpd, each being fired with both "1 in 3" and "1 in 6" patterns.

[0019] For this arrangement, it will be seen that the advantageous values of T at which velocity variation is minimised occur at around T= 3, 7, 11 and 15 μs - corresponding to 1.5, 3.5, 5.5 and 7.5L/C respectively - resulting in droplet ejection velocities, U, in the region of 9, 7, 5 and7 m/s respectively. The first of these values is to be preferred for actual printhead operation, however, since higher values of T result not only in lower droplet ejection velocities but also a greater waveform duration overall and a correspondingly lower dot printing rate. For acceptable print quality - i.e. to ensure accurate placement of printed dots on a substrate - a droplet ejection velocity of at least 5 m/s - and preferably at least 7 m/s has been found to be necessary.

[0020] Figure 5 is a plot of the velocity (U1,U2) of first and second droplets ejected from a printhead of the kind used to obtain figure 2 against total waveform duration T. It is believed to offer an explanation of the behaviour shown in figure 2, namely that at certain values of T the velocity U2 of the second droplet to be ejected is greater than the velocity U1 of the first droplet to be ejected. The second droplet consequently hits the first droplet from the rear, the resulting larger, merged drop having a velocity greater than U1 (by conservation of momentum). This corresponds to the velocity peaks in the "1 in 3"/7 dpd and "1 in 6"/7 dpd curves of figure 2. In contrast, there are other values of T where U1 and U2 are sub-

stantially equal and velocity differences between single and multiple droplet ejection are minimised. The aforementioned advantageous operation points occur where these minima coincide with points of minimum velocity variation due to changes in printing pattern between "1 in 3" operation and "1 in 6" operation.

[0021] A similar increase in ejection velocity over previously ejected droplets has been noticed in the ejection of the third and subsequent droplets of a train of seven droplets. It is believed that this behaviour corresponds to a build up in the acoustic energy remaining in an ink channel at the end of each actuation waveform. It is further believed that, at the advantageous operation points mentioned above, interaction between successive waveforms is such as to cancel out this residual acoustic energy, resulting in the ejection of successive droplets at uniform velocity.

[0022] As mentioned above, the "DRR" waveform shown in figure 3a need not necessarily have channel contraction and expansion elements that are equal in duration and/or amplitude. Indeed, it is believed that the duration of the contraction element of the waveform may have more influence on the behaviour discussed above than the duration of the actuation waveform as a whole.

[0023] Figure 6 illustrates the variation with increasing contraction period duration (DR) of the peak-to-peak waveform amplitude (V) necessary to achieve a droplet ejection velocity (U) of 5 m/s. As with figures 2 and 4, the printhead was of the kind disclosed in WO95/25011 and having a period of longitudinal oscillation of pressure waves in the channel, 2L/c, of approximately 4.4μs. It will be seen that at values of contraction period duration (DR) of around 2.5μs and 4.5μs, different values of waveform amplitude V are necessary depending on the droplet firing regime.

[0024] In the case of DR=2.5μs, a peak-to-peak waveform amplitude (V) of only 27 volts is required when applying the waveform seven times in immediate succession so as to eject seven droplets (7 drops per dot (dpd)) from one in every three channels ("1 in 3" operation) in multipulse greyscale printing mode. In contrast, a value of V=32 volts is necessary to achieve the same droplet ejection velocity when applying the waveform only once so as to eject a single droplet (1 drop per dot (dpd)) from one in every six channels ("1 in 6" operation).

[0025] In practice, variation of waveform amplitude with droplet firing regime would require complex - and thus expensive - control electronics. The alternative solution of a constant waveform amplitude, whilst simpler and cheaper to implement, would give rise to variations in droplet ejection velocity and consequential droplet placement errors as discussed above. Preferably, the method comprises the step of:

applying a plurality of electrical signals to the electrically actuable means associated with said channel in accordance with the print tone data, each electrical signal being held at a given non-zero level for a period, the duration of the period being selected such that the velocity of the droplet ejected from said channel in response to said signal is substantially independent of (a) whether or not channels in the vicinity of said channel are similarly actuated to effect drop ejection simultaneously with drop ejection from said channel, and (b) the number of droplets to be ejected in accordance with the print tone data.

[0026] This results from the discovery that there are values of contraction period duration (DR) at which the droplet ejection velocity remains substantially constant regardless of the droplet firing regime. Operation in such ranges allows waveforms of constant amplitude to be used regardless of operating regime and therefore without the risk of droplet placement errors.

[0027] In the case of figure 6, for example, such constant behaviour occurs in the approximate ranges 1.8μs ≤ DR ≤ 2.2μs (corresponding voltage waveform amplitude approximately 31.5 volts), with particularly close agreement between velocities being achieved at around 2.2μs, and in the range 3.0μs ≤ DR ≤ 3.6μs (corresponding voltage waveform amplitude in the range 34-39 volts), particularly 3.4μs. Expressed in terms of half period of oscillation, L/c, these ranges are approximately 0.8L/c ≤ DR ≤ 1.0L/c, particularly 1L/c, and 1.4L/c ≤ DR ≤ 1.6L/c, particularly 1.5L/c. Operation in the lower rather than the higher range gives a lower overall waveform duration which in turn allows a higher waveform repetition frequency. The lower operating voltage for a given droplet speed in the 1.8μs ≤ DR ≤ 2.2μs range also gives rise to correspondingly lower heat generation in the piezoelectric material of the printhead actuator walls. For these reasons, operation in the lower range is to be preferred.

[0028] It should be appreciated that printhead characteristics obtained for a constant droplet ejection velocity (U), as shown in figure 6, will include consistent fluid dynamic effects such as nozzle and ink inlet impedance which are themselves known, for example, from WO92/12014 incorporated herein by reference. The characteristics will incorporate viscosity variations, however, brought about by a variation in heating of the ink by the piezoelectric material of the printhead with variation in waveform amplitude (V). Piezoelectric heating of ink in a printhead is explained in WO97/35167, incorporated herein by reference, and consequently will not be discussed in further detail here.

[0029] Conversely, printhead characteristics of the kind shown in figures 2,4 and obtained for a constant waveform amplitude (V) will include consistent heating effects at the expense of varying fluid dynamic effects. It will be appreciated, however, that at those operating conditions according to the present invention at which waveform amplitude and droplet ejection velocity remain constant regardless of operating regime, fluid dy-

namic and piezoelectric heating effects will also remain constant. Consequently either type of characteristic is suitable in determining operating conditions according to the present invention.

[0030] Figure 7 illustrates the actuating waveform used in obtaining the characteristics of figure 6, with actuating voltage magnitude being indicated on the ordinate and normalised time on the abscissa. At "C" is indicated the channel contraction period, the duration (DR) of which is varied to obtain the characteristics of figure 6. There follows immediately a channel expansion period "X" of duration of 2DR, followed by a period "D" of duration 0.5DR in which the channel dwells in a condition in which it is neither contracted or expanded. Following the dwell period, the waveform can be repeated as appropriate to eject further droplets. Such a waveform has been found to be particularly effective in ejecting multiple droplets to form a single, variable-size, dot on a substrate without simultaneously causing the ejection of unwanted droplets (so called "accidentals") from neighbouring channels.

[0031] Figure 6 et seq. were obtained using the described waveform in a printhead having a period of longitudinal oscillation of pressure waves in the channel (2Lc) of approximately 4.4μs, a nozzle outlet diameter of 25μm, and a hydrocarbon ink of the kind disclosed in W096/24642. Other parameters were typical, for example as disclosed in EP 0609080, EP 0611154, EP 0611655 and EP 0612623.

[0032] As explained above, for a given printhead design operating at a given peak-to-peak actuating voltage, it is possible to empirically determine advantageous operation points at which the velocity of an droplet ejected from a channel remains independent both of the number of droplets to be ejected from that channel to form a single printed dot on the substrate and of whether or not neighbouring channels are also actuated to effect droplet ejection.

[0033] There remains, however, the potential problem outlined in W097/35167 of a variation in ink viscosity - and a resulting variation in droplet ejection velocity with the frequency at which droplet ejection takes place. In the case of a printhead utilising chambers the volume of which is variable by a piezoelectric actuating mechanism, for example, such viscosity variation is attributable to a variation in ink temperature which in turn is due to a variation with operating frequency in the amount of heat transferred to the ink from the piezoelectric material of the actuating mechanism for each chamber.

[0034] Figure 8 shows such a variation in droplet ejection velocity (U) with peak-to-peak amplitude (V) for the printhead described above when operated according to the following droplet ejection regimes: (a) single droplet (1dpd), low (1dc) frequency operation; (b) single droplet (1dpd), high (104dc) frequency operation; (c) seven droplet (7dpd), low (1dc) frequency operation; (d) seven droplet (7dpd), high (104dc) frequency) operation, whereby 1dc ("drop count") corresponds to a dot printing frequency of 60Hz - a dot being formed by the ejection from a channel of one or more droplets in response to the application of one or more actuating waveforms - and 104 dc corresponds to a dot printing frequency of 6.2kHz. In the particular example, actuation was by the waveform of figure 7 with the advantageous DR value of 2.2μs as determined from figure 6.

[0035] Comparing characteristics (a) and (b), it will be seen that, at any given value of peak-to-peak waveform amplitude (V), the droplet ejection velocity (U) from a channel firing at 6.2kHz is between 3 and 5 m/s (on average 4 m/s) greater than the value of U for a channel firing at 60Hz. Furthermore, the value (Vmin) of waveform amplitude below which droplet ejection no longer takes place is lower (29V giving 4 m/s) at the higher firing frequency that at the lower firing frequency (30V giving 2 m/s). There is also a corresponding reduction in the value, Vmax, of waveform amplitude above which the printhead is no longer able to eject droplets due, amongst other things, to the known problem of air-sucking.

[0036] Similar patterns are evident in the seven droplet per dot characteristics (c) and (d), with a difference in U at a given V of around 7m/s and a Vmin value of approximately 2 m/s at 30V at 60Hz compared with a value of 5 m/s at 25V when firing at 6.2kHz.

[0037] It will also be noted that the range of waveform amplitude values (V) over which droplet ejection takes place decreases from 30 or more volts in the 1dpd/1dc and 1dpd/104dc regimes (a) and (b) to only 6 volts in the 7dpd/104dc regime (d). In particular, the maximum values of amplitude at which droplet ejection takes place (Vmax) reduce with regime from 50V (giving U=21m/s) in regime (a) to 31V (giving U=10m/s) in regime (d). Conversely, performance at lower voltages increases with drops per dot / drop count, with an amplitude of only 25 volts being required to effect droplet ejection (at 4.5m/s) in regime (d) as against the 30 volts needed to eject a droplet (at 2.5m/s) in regimes (a) and (b). This behaviour is believed to be attributable to a reduction in ink viscosity brought about by increased heat generation in the piezoelectric actuator when operated to eject higher numbers of drops per dot.

[0038] As already mentioned, a droplet ejection speed of at least 5 m/s is necessary for effective image formation. In the case of a printhead operating in accordance with figure 8, it will be noted that there is no common value of V at which droplet ejection in excess of 5 m/s can be obtained for all operating regimes. Such a printhead is said to have no operating window.

[0039] The solution to the above problem is also described in the aforementioned WO97/35167 and entails supplying the actuating mechanism of each chamber with one of several voltage waveforms depending on whether droplet ejection is required. Where incoming print data dictates that droplet ejection is to take place, a waveform according to the present invention - for example having an advantageous DR value of the kind dis-

cussed with regard to figures 6 and 7 - can be applied. Alternatively, where no droplet ejection is to take place, there is applied a waveform that is insufficient to effect droplet ejection yet sufficient to generate an amount of heat in the piezoelectric material of the actuating mechanism to keep the ink in the chamber at the same temperature (and thus viscosity) as its droplet-ejecting neighbours.

[0040] Such a non-ejecting waveform shape is known from the aforementioned WO97/35167, repeated in figure 9 for convenience. It is particularly suited to printheads in which actuator walls are defined between ink channels each having a channel electrode, successive channels in the printhead being alternately allocated to one of three groups which themselves are enabled one after another for droplet ejection. Such operation is well-known - e.g. from WO95/25011 - and consequently will not be discussed in greater detail.

[0041] By offsetting by an amount "P" the voltage pulse 60 applied to a channel belonging to an enabled channel group relative to voltage pulses 70 applied to neighbouring channels belonging to non-enabled groups, it is possible to generate across the actuator walls bounding that enabled channel an actuation waveform, shown at 80 in figure 9, that has the same value of peak-to-peak amplitude (V) as a corresponding droplet-ejecting waveform but a duration of contraction and expansion periods reduced to a level where heat generation - but no droplet ejection - takes place. Alternative non-ejecting waveforms in which amplitude rather than duration is reduced to a non-ejecting level may equally well be used. Examples are disclosed in WO97/35167.

[0042] Figure 10a is an example of the ejecting and non-ejecting actuation waveforms that might be applied to three neighbouring channels belonging to three successively-enabled channel groups A,B and C in the case where the incoming print data specifies 100%, 0% and 42% (3/7) print density respectively.

[0043] In the period 100 of enablement of the channel belonging to group A, seven droplet ejecting waveforms 110 of the kind shown in figure 7 are applied in immediate succession, thereby to eject seven droplets to form a single, maximum-size dot on the substrate.

[0044] In the subsequent period 120 of enablement of the channel belonging to group B, seven non-ejecting waveforms 130 of the kind shown in figure 7 are applied in immediate succession. No droplets are ejected - giving the desired 0% print density - but sufficient heat is generated in the printhead actuator walls and transferred to the ink to maintain the ink at substantially the same temperature as if the channel had been actuated to eject seven drops.

[0045] During the period of enablement 140 of the channel belonging to group C, three ejecting waveforms 150 followed by four non-ejecting waveforms 160 are applied, thereby to eject three out of a possible seven droplets to form a 42% sized printed dot yet maintain the ink in that channel at temperature corresponding to seven drop ejection.

[0046] Cycles A, B and C are subsequently repeated, droplets being ejected in accordance with print data.

[0047] Figure 10b illustrates the corresponding voltage waveforms applied to the channel electrodes of the three neighbouring channels to generate the actuating waveforms shown in figure 10a.

[0048] As explained in WO97/35167, the necessary level of heat generation by a non-ejecting waveform may be established by a simple process of trial and error. Figure 11 shows the effect of varying the offset, P, referred to above for a channel actuated at a frequency of 6.2kHz (the aforementioned "104dc" operation), the first cycle comprising a train of seven droplet-ejecting waveforms - as per cycle A in figure 10a - and the following 103 cycles each comprising a train of seven non-ejecting waveforms as per cycle B of figure 10a. P values for the non-ejecting waveforms are given as a fraction of the contraction period (DR) of the equivalent, droplet-ejecting waveform. There is also shown a characteristic for a "7dpd/104dc" operation in which the channel is repeatedly actuated at a frequency of 6.2 kHz with a train of seven droplet-ejecting waveforms.

[0049] It will be seen that the 7dpd/1dc characteristics form a series in which the ejection velocity U at a given actuating voltage amplitude V increases with P. The 7dpd/104dc characteristic does not form part of this series, but is almost coincident with the characteristic for 7dpd/1dc, P=0.35, i.e. there is little difference between the velocity of droplets ejected by the two waveforms. This indicates that a non-ejecting waveform having P=0.35 gives a degree of ink heating which most closely matches that generated during droplet ejection, taking account of the heat that is taken out of the ink channel by the ink droplet itself.

[0050] Whilst the value of P=0.35 is believed to apply to all printheads having similar thermal conduction properties to those of the general printhead construction outlined above, it will be understood that other printhead designs may well have different thermal conduction properties. Similar considerations apply to the ink used in the printhead. In such cases, different values of P will be necessary, to be determined by an iterative process such as outlined above. Reference to WO97/35167 is made in this regard.

[0051] The higher velocities of the characteristics having P greater than 0.35 (i.e 20P=0.4 and greater) correspond to an amount of heat being given to the ink by a non-ejecting waveform that actually exceeds that generated during normal droplet ejection.

[0052] Figure 12 illustrates the performance of the printhead used to obtain figure 8 when operated using a non-ejecting waveform having P=0.35 as determined in the simple trial and error method outlined above. It is clear from the figure that droplet ejection velocity U is independent of whether one or seven droplets are ejected to form a printed dot on a substrate and/or whether the train of one or seven droplets is repeated at a fre-

quency of 60Hz or 6.2kHz. Droplet ejection regardless of regime will be seen to take place for voltage waveform amplitudes in the approximate range 26-30 volts giving rise to the corresponding ejection velocity range of approximately 4-10 m/s.

[0053] Figure 13 is a detailed view of figure 12 showing the operating window W of approximately 3.6V within which droplet ejection velocity U (in the approximate range 5-9.5 m/s) remains greater than or equal to 5m/s and substantially independent of the number of droplets ejected in a train to form a printed dot on the substrate and of the frequency at which such a train is repeated. This is in contrast to the operation described above with reference to figure 8 and having no operating window. Further, as mentioned above, the choice of droplet ejection waveform in accordance with the invention, ensures that the droplet ejection velocity also remains substantially independent of whether or not channels in the vicinity of the firing channel are similarly actuated to effect droplet ejection.

[0054] The use of non-ejecting pulses as described above also makes the system as a whole more energetic with the result that, for ejection regimes (a) - (c) at least, droplet ejection begins at a lower value of amplitude (Vmin) than when operated without such pulses as per figure 8.

[0055] Whilst specific reference has been made to apparatus as described in WO95/25011, the present invention may be applicable to a wide range of ink jet apparatus, particularly apparatus in which a channel dividing side wall is displaceable in either of two opposing directions. Similarly, the term ink jet may include the ejection of substances other than ink to form an image on a substrate.

Claims

1. A method of operating an inkjet printhead for printing on a substrate, the printhead having an array of channels;

   a series of nozzles which communicate respectively with said channels for ejection of droplets therefrom;

   connection means for connecting the channels with a source of ink;

   and electrically actuable means associated with each channel and actuable a plurality of times in accordance with print tone data, thereby to eject a corresponding number of droplets to form a printed dot of appropriate tone on the substrate;

   the method being **characterised by** the steps of:

   applying a one or a plurality of electrical signals to the electrically actuable means associated with a channel in accordance with the print tone data, either the duration of each signal or, where each signal is held at a given non-zero level for a period, the duration of the period being selected such that the velocity of the droplet ejected from said nozzle in response to said signal is substantially independent of (a) whether or not the electrically actuable means of the channels in the vicinity of said channel are similarly actuated to effect drop ejection simultaneously with drop ejection from said nozzle, and (b) the number of droplets to be ejected in accordance with the print tone data.

2. Method according to claim 1, wherein successive channels of the array are regularly assigned to groups such that a channel belonging to any one group is bounded on either side by channels belonging to at least one other group;

   the groups of channels being sequentially enabled for actuation in successive periods;

   the duration of each signal being chosen such that the velocity of a droplet, ejected from said channel in response to said signal, is substantially independent of (a) whether or not those channels belonging to the same group as said the channel and which are located nearest in the array to said channel are similarly actuated to effect droplet ejection simultaneously with drop ejection from said channel; and (b) the number of droplets to be ejected in accordance with the print tone data.

3. Method according to claim 1 or 2, wherein the ratio of the duration of each signal to the half period of oscillation of longitudinal pressure waves in said channel lies in the ranges 1.5 - 1.9 or 3.5 - 3.8 or in the vicinity of the values 5.5 and 7.5.

4. Method according to any previous claim, wherein said electrically actuable means are adapted to vary the volume of said channel, thereby to effect droplet ejection therefrom.

5. Method according to claim 4, wherein said electrical signal effects an expansion of said channel followed by a contraction of said channel.

6. Method according to claim 5, wherein said channel is held in expanded and contracted states for equal periods of time.

7. A method according to Claim 1, comprising the step of:

   applying a plurality of electrical signals to the electrically actuable means associated with said channel in accordance with the print tone data, each electrical signal being held at a given non-zero level for a period, the duration of the period being selected such that the velocity

of the droplet ejected from said channel in response to said signal is substantially independent of (a) whether or not channels in the vicinity of said channel are similarly actuated to effect drop ejection simultaneously with drop ejection from said channel, and (b) the number of droplets to be ejected in accordance with the print tone data.

8. Method according to claim 7, wherein successive channels of the array are regularly assigned to groups such that a channel belonging to any one group is bounded on either side by channels belonging to at least one other group;

the groups of channels being sequentially enabled for actuation in successive periods;

each electrical signal being held at a given non-zero level for a period, the duration of the period being selected such that the velocity of a droplet, ejected from said channel in response to said signal, is substantially independent of (a) whether or not those channels belonging to the same group as said channel and which are located nearest in the array to said channel are similarly actuated to effect droplet ejection simultaneously with drop ejection from said channel, and (b) the number of droplets to be ejected in accordance with the print tone data.

9. Method according to claim 7 or 8, wherein the ratio of the duration of the period for which each electrical signal is held at a given non-zero level to the half period of oscillation of longitudinal pressure waves in said channel lies in the ranges 0.8 to 1.0 or 1.4 to 1.6.

10. Method according to any of claims 7 to 9, and wherein the electrical signal being held at said given non-zero level effects an increase in the volume of said channel.

11. Method according to claim 10, wherein said electrical signal effects an expansion of said channel followed by a contraction of said channel.

12. Method according to claim 11, wherein said channel is held in an expanded and contracted states of equal periods of time.

13. Method according to any previous claim, wherein said plurality of electrical signals are applied in immediate succession.

14. Method according to any previous claim, wherein successive electrical signals are separated in time by a dwell period.

15. Method according to any previous claim, wherein a number of further electrical signals is applied to the electrically actuable means, each further signal causing a change in temperature of the droplet fluid in said channel without causing droplet ejection, said change in temperature being substantially equal to that caused by the application of an electrical signal to effect ejection of a droplet.

16. Method according to claim 15, wherein droplets to form a printed dot on the substrate are ejected in a droplet ejection period, the sum of the number of electrical signals and the number of further electrical signals applied being constant for successive droplet ejection periods.

17. Method according to claim 15 or 16, wherein said further electrical signal is held at a given non-zero level for a further period.

18. Method according to claim 17, wherein the ratio of the duration of said further period to the duration of said period at which said electrical signal is held at a given non-zero level is less than one.

19. Method according to claim 18, wherein the ratio is less than 0.4.

20. Method according to claim 19, wherein the ratio is approximately 0.35.

21. Method according to any of claims 17 to 20, wherein said further electrical signal is held at a first given non-zero level for a first further period and thereafter at a second given non-zero level for a second further period, said first and second given non-zero levels being of opposite sign.

22. Method according to claim 1, wherein said first and second further periods are of equal duration.

23. Method according to any previous claim, wherein the velocity of the ejected droplet is at least 5 m/s, preferably at least 7 m/s.

24. Method according to any previous claim, wherein the half period of oscillation of longitudinal pressure waves in the ink in the channel has a value not exceeding 5 μs, preferably not exceeding 2.5 μs.

25. An inkjet printhead for printing on a substrate:

the printhead having an array of channels;
a series of nozzles which communicate respectively with said channels for ejection of droplets therefrom;
connection means for connecting the channels with a source of ink;
electrically actuable means associated with each channel and actuable a plurality of times

in accordance with print tone data, thereby to eject a corresponding number of droplets to form a printed dot of appropriate tone on the substrate;
and a drive circuit for applying the electrical signals one or a plurality of times to the electrically actuable means associated with a channel in accordance with the print tone data, **characterised in that** the drive circuit is configured to either apply each electrical signal for a duration selected such that, or hold each signal at a given non-zero level for a period, the duration of the period being selected such that the velocity of the droplet ejected from said nozzle in response to said signal is substantially independent of (a) whether or not the electrically actuable means of the channels in the vicinity of said channel are similarly actuated to effect drop ejection simultaneously with drop ejection from said nozzle, and (b) the number of droplets to be ejected in accordance with the print tone data.

26. A drive circuit for an inkjet printhead for printing on a substrate:

the printhead having an array of channels;
a series of nozzles which communicate respectively with said channels for ejection of droplets therefrom;
connection means for connecting the channels with a source of ink;
and electrically actuable means associated with each channel and actuable a plurality of times in accordance with print tone data, thereby to eject a corresponding number of droplets to form a printed dot of appropriate tone on the substrate;

said drive circuit being configured to apply the electrical signals one or a plurality of times to the electrically actuable means associated with a channel in accordance with the print tone data, **characterised in that** the drive circuit is configured to either apply each electrical signal for a duration selected such that, or hold each signal at a given non-zero level for a period, the duration of the period being selected such that the velocity of the droplet ejected from said nozzle in response to said signal is substantially independent of (a) whether or not the electrically actuable means of the channels in the vicinity of said channel are similarly actuated to effect drop ejection simultaneously with drop ejection from said nozzle, and (b) the number of droplets to be ejected in accordance with the print tone data.

Patentansprüche

1. Verfahren zum Betrieb eines Tintenstrahl-Druckkopfes, zum Drucken auf einem Substrat, wobei der Druckkopf ein Feld von Kanälen;

eine Serie von Düsen, die jeweilig mit den Kanälen für den Auswurf von Tröpfchen daraus kommunizieren;

Verbindungsmittel für die Verbindung der Kanäle mit einer Tintenquelle; und ein elektrisch schaltbares bzw. betätigbares Mittel, das mit jedem Kanal verbunden ist und in Übereinstimmung mit den Druckton-Daten vielfach schaltbar bzw. betätigbar ist, um dadurch eine entsprechende Anzahl von Tröpfchen auszuwerfen um einen gedruckten Punkt eines angemessenen Farbtons auf dem Substrat zu formen bzw. zu bilden, hat;

wobei das Verfahren durch die folgenden Schritte **gekennzeichnet** ist:

Anlegung eines einzelnen elektrischen Signals oder einer Vielzahl von elektrischen Signalen, an das elektrisch schaltbare bzw. betätigbare Mittel, das mit einem Kanal in Übereinstimmung mit den Druckton-Daten verbunden ist, wobei entweder die Dauer von jedem Signal oder, wo jedes Signal bei einer gegebenen Nicht-Null-Stufe bzw. Höhe für eine Periode gehalten wird, die Dauer von der Periode, derart ausgewählt wird, dass die Geschwindigkeit des Tröpfchens, das in Antwort auf das Signal von der Düse ausgeworfen wird, im wesentlichen unabhängig ist von (a) ob oder ob nicht das elektrisch schaltbare bzw. betätigbare Mittel von den Kanälen in der Nähe von dem Kanal ähnlich betätigt wird, um den Tröpfchenauswurf gleichzeitig mit dem Tröpfchenauswurf von der Düse zu bewirken, und (b) der Anzahl von Tröpfchen, die in Übereinstimmung mit den Druckton-Daten ausgeworfen werden.

2. Verfahren nach Anspruch 1, bei welchem aufeinanderfolgende Kanäle des Feldes regelmäßig Gruppen zugewiesen werden, so dass ein Kanal, der zu irgendeiner Gruppe gehört, auf beiden Seiten durch Kanäle verbunden ist bzw. gebunden ist, die wenigstens zu einer anderen Gruppe gehören;

wobei die Gruppen von Kanälen sequentiell zur Betätigung in aufeinanderfolgenden Perioden freigegeben werden;

wobei die Dauer eines jeden Signals derartig gewählt wird, dass die Geschwindigkeit eines Tröpfchens, das von einem Kanal als Antwort auf das Signal ausgestoßen bzw. ausgeworfen wird, im wesentlichen unabhängig ist von (a) ob oder ob nicht Kanäle die zu der selben Gruppe wie der genannte Kanal gehören und die in dem Feld am nächsten zu dem Kanal sich befinden, ähnlich be-

tätigt werden, um einen Tröpfchenausstoß bzw. einen Tröpfchenauswurf gleichzeitig mit dem Tröpfchenausstroß von dem Kanal zu bewirken, und (b) die Anzahl der auszustoßenden Tröpfchen in Übereinstimmung mit den Druckton-Daten ist.

3. Verfahren nach Anspruch 1 oder 2, bei welchem das Verhältnis der Dauer von jedem Signal zu der halben Periode der Schwingung von longitudinalen Druckwellen in dem genannten Kanal in den Bereichen 1,5 bis 1,9 oder 3,5 bis 3,8 oder in der Nähe der Werte 5,5 und 7,5 liegt.

4. Verfahren nach irgendeinem vorherigen Anspruch, bei welchem das elektrisch schaltbare bzw. betätigbare Mittel angepasst wird, um das Volumen des Kanals zu variieren, um dadurch den Tröpfchen-Auswurf daraus zu bewirken.

5. Verfahren nach Anspruch 4, bei welchem das elektrische Signal eine Expansion des Kanals gefolgt von einer Kontraktion des Kanals bewirkt.

6. Verfahren nach Anspruch 5, bei welchem der Kanal im erweiterten und zusammengezogenen Stadium für gleiche Zeitperioden gehalten wird.

7. Verfahren nach Anspruch 1, das die folgenden Schritte umfasst:

eine Vielzahl von elektrischen Signalen werden an das elektrisch betätigbare Mittel angelegt, das dem Kanal in Übereinstimmung mit den Druck-Farbton-Daten zugeordnet ist, wobei jedes elektrische Signal bei einem gegebenen Nicht-Null-Niveau für eine Periode gehalten wird, wobei die Dauer der Periode derartig ausgewählt wird, dass die Geschwindigkeit des Tröpfchens, das von dem Kanal als Antwort auf das Signal ausgestoßen wird, im wesentlichen unabhängig ist von (a) ob oder ob nicht Kanäle in der Nähe des Kanals ähnlich betätigt werden, um einen Tröpfchenausstoß gleichzeitig mit einem Tröpfchenausstoß von dem Kanal zu bewirken, und (b) die Anzahl der Tröpfchen, die in Übereinstimmung mit den Druck-Farbton-Daten auszustoßen ist.

8. Verfahren nach Anspruch 7, bei welchem aufeinanderfolgende Kanäle des Feldes regelmäßig Gruppen zugeordnet werden, derartig, dass ein Kanal, der zu irgendeiner Gruppe gehört, an beiden Seiten bzw. jeder Seite durch Kanäle gebunden wird bzw. eingebunden wird, die wenigstens zu einer anderen Gruppe gehören;

wobei die Gruppe der Kanäle sequentiell zur Betätigung in aufeinanderfolgenden Perioden freigegeben wird;

jedes elektrische Signal bei einem gegebenen Nicht-Null-Stufe für eine Periode gehalten wird, wobei die Dauer der Periode derartig ausgewählt wird, dass die Geschwindigkeit eines Tröpfchens, das von dem Kanal in Antwort auf das Signal ausgestoßen wird, im wesentlichen unabhängig ist von (a) ob oder ob nicht jene Kanäle, die zur der selben Gruppe wie der Kanal gehören und die am nächsten in dem Feld zu dem Kanal sich befinden, ähnlich betätigt werden, um einen Tröpfchenausstoß gleichzeitig mit dem Tröpfchenausstoß von dem Kanal bewirken, und (b) die Anzahl der Tröpfchen, die in Übereinstimmung mit den Druck-Farbton-Daten auszustoßen sind.

9. Verfahren nach Anspruch 7 oder 8, bei welchem das Verhältnis von der Dauer der Periode, für welches jedes elektrische Signal bei einer gegebenen Nicht-Null-Stufe gehalten wird, zu der halben Periode der Schwingung der longitudinalen Druckwelle in dem Kanal in den Bereichen 0,8 bis 1,0 oder 1,4 bis 1,6 liegt.

10. Verfahren nach irgendeinem der Ansprüche 7 bis 9, bei welchem das elektrische Signal, das bei einer gegebenen Nicht-Null-Stufe gehalten wird, ein Ansteigen des Volumens des Kanals bewirkt.

11. Verfahren nach Anspruch 10, bei welchem das elektrische Signal eine Expansion des Kanals gefolgt von einer Kontraktion des Kanals bewirkt.

12. Verfahren nach Anspruch 11, bei welchem der Kanal in einem erweiterten und zusammengezogenen Stadium für gleiche Zeitperioden gehalten wird.

13. Verfahren nach irgendeinem vorherigen Anspruch, bei welchem die Vielzahl von elektrischen Signalen in unmittelbarer Reihenfolge bzw. Abfolge angelegt bzw. angewandt werden.

14. Verfahren nach irgendeinem vorherigen Anspruch, bei welchem aufeinanderfolgende elektrische Signale durch eine Verweilperiode zeitlich getrennt werden.

15. Verfahren nach irgendeinem vorherigen Anspruch, bei welchem eine Anzahl von weiteren elektrischen Signalen an das elektrische schaltbare bzw. betätigbare Mittel angelegt bzw. angewandt werden, wobei jedes weitere Signal eine Veränderung der Temperatur der Tröpfchen-Flüssigkeit in dem Kanal bewirkt, ohne einen Tröpfchenauswurf zu verursachen, wobei die Änderung der Temperatur im wesentlichen gleich zu jenen ist, die durch die Anwendung eines elektrischen Signals, um einen Auswurf eines Tröpfchens zu bewirken, verursacht wird.

16. Verfahren nach Anspruch 15, bei welchem Tröpfchen, um einen gedruckten Punkt auf einem Substrat zu bilden, in einer Tröpfchen-Auswurf-Periode ausgeworfen wurde, wobei die Summe von der Anzahl von elektrischen Signalen und der Anzahl von weiteren angelegten bzw. angewendeten elektrischen Signalen für aufeinanderfolgende Tröpfchen-Auswurf-Perioden konstant ist.

17. Verfahren nach Anspruch 15 oder 16, bei welchem das weitere elektrische Signal bei einer gegebenen Nicht-Null-Stufe für eine weitere Periode gehalten werden.

18. Verfahren nach Anspruch 17, bei welchem das Verhältnis der Dauer der weiteren Periode zu der Dauer der genannten Periode, bei der das elektrische Signal bei einer gegebenen Nicht-Null-Stufe gehalten wird, weniger als 1 ist.

19. Verfahren nach Anspruch 18, bei welchem das Verhältnis weniger als 0,4 ist.

20. Verfahren nach Anspruch 19, bei welchem das Verhältnis ungefähr 0,35 ist.

21. Verfahren nach irgendeinem Anspruch 17 bis 20, bei welchem das weitere elektrische Signal bei einer ersten gegebenen Nicht-Null-Stufe für eine erste weitere Periode und danach bei einer zweiten gegebenen Nicht-Null-Stufe für eine zweite weitere Periode gehalten wird, wobei die erste und zweite gegebene Nicht-Null-Stufe entgegengesetzte Vorzeichen bzw. Werte besitzen.

22. Verfahren nach Anspruch 1, bei welchem die erste und zweite weitere Periode die gleiche Dauer haben.

23. Verfahren nach irgendeinem vorherigen Anspruch, bei welchem die Geschwindigkeit von dem ausgeworfenen Tröpfchen zumindest 5 m/s, vorzugsweise zumindest 7 m/s ist.

24. Verfahren nach irgendeinem vorherigen Anspruch, bei welchem die halbe Periode der Schwingung von longitudinalen Druckwellen in der Tinte in dem Kanal, einen Wert besitzt, der 5 µs nicht übersteigt, vorzugsweise 2,5 µs nicht übersteigt.

25. Tintenstrahl-Druckkopf zum Drucken auf einem Substrat:

wobei der Druckkopf ein Feld von Kanälen; eine Reihe von Düsen, die jeweilig mit den Kanälen zum Auswurf bzw. Ausstoßen von Tröpfchen davon kommunizieren; ein Verbindungsmittel zum Verbinden des Kanals mit einer Tintenquelle; ein elektrisch betätigbares Mittel, die mit jedem Kanal verbunden sind und eine Vielzahl von Malen in Übereinstimmung mit Druckton-Daten betätigbar ist, um dadurch eine entsprechende Anzahl von Tröpfchen auszustoßen; um einen gedruckten Punkt eines angemessenen bzw. passenden Tons auf dem Substrat zu drukken; und eine Treiberschaltung zum Anlegen der elektrischen Signale einmal oder eine Vielzahl von Malen an das elektrisch betätigbare Mittel, das mit einem Kanal in Übereinstimmung mit den Druckton-Daten verbunden ist, bzw. in Zusammenhang steht; hat, **dadurch gekennzeichnet, dass** die Treiberschaltung gestaltet bzw. angeordnet ist, um entweder jedes elektrische Signal für eine Dauer anzulegen, die derartig ausgewählt ist, dass, oder jedes Signal bei einem gegebenen Nicht-Null-Niveau für eine Periode zu halten, wobei die Dauer der Periode derartig ausgewählt wird, dass die Geschwindigkeit des Tröpfchens, das von der Düse in Antwort auf das Signal ausgestoßen wird, im wesentlichen unabhängig ist von (a) ob oder ob nicht das elektrisch betätigbare Mittel der Kanäle in der Nähe des Kanals ähnlich betätigt wird, um einen Tröpfchen-Ausstoß gleichzeitig mit einem Tröpfchen-Ausstoß von der Düse zu bewirken, und (b) der Anzahl von Tröpfchen, die in Übereinstimmung mit dem Druckton-Daten auszustoßen ist.

26. Treiberschaltung für einen Tintenstrahl-Druckkopf zum Drucken auf einem Substrat:

wobei der Druckkopf ein Feld von Kanälen; eine Reihe von Düsen, die jeweilig mit den Kanälen zum Ausstoß von Tröpfchen davon verbunden sind; ein Verbindungsmittel zum Verbinden mit einer Tintenquelle; und ein elektrisch betätigbares Mittels, das jedem Kanal zugeordnet ist und eine Vielzahl von Malen in Übereinstimmung mit Druckton-Daten betätigbar ist, um dadurch eine entsprechende Anzahl von Tröpfchen auszustößen, um einen gedruckten Punkt passenden Tons auf dem Substrat zu drucken; hat;

wobei die Treiberschaltung aufgebaut bzw. gestaltet ist, um die elektrischen Signale einmal oder eine Vielzahl von Malen an das elektrisch betätigbare Mittel anzulegen, das einem Kanal in Übereinstimmung mit den Druckton-Daten zugeordnet ist, **dadurch gekennzeichnet, dass** die Treiberschaltung aufgebaut bzw. gestaltet ist, um entweder jedes elektrische Signal für eine Dauer anzulegen, die derartig ausgewählt ist, dass, oder jedes Signal bei einem gegebenen Nicht-Null-Ni-

veau für eine Periode zu halten, wobei die Dauer der Periode derartig ausgewählt wird, dass die Geschwindigkeit des Tröpfchen, das von der Düse in Antwort zu dem Signal ausgestoßen wird, im wesentlichen unabhängig ist, von (a) ob oder ob nicht das elektrische betätigbare Mittel der Kanäle in der Mitte des Kanals ähnlich betätigt wird, um eine Tröpfchenausstoß gleichzeitig mit einem Tröpfchenausstoß von der Düse zu bewirken, und (b) die Anzahl der Tröpfchen, die in Übereinstimmung mit den Druckton-Daten auszustoßen sind.

Revendications

1. Procédé de fonctionnement d'une tête d'impression à jet d'encre pour impression sur un substrat, la tête d'impression comprenant :

   une série de canaux ;
   une série de buses qui communiquent respectivement avec les dits canaux pour éjection de gouttelettes à partir de ceux-ci ;
   des moyens de connexion pour connecter les canaux à une source d'encre ; et
   des moyens électriquement excitables associés à chaque canal et excitables une pluralité de fois conformément à des données de ton d'impression, afin d'éjecter un nombre correspondant de gouttelettes pour former un point imprimé de ton approprié sur le substrat ;

   le procédé étant **caractérisé par** les étapes de :

   application d'un signal ou d'une pluralité de signaux électriques aux moyens électriquement excitables associés à un canal conformément aux données de ton d'impression, la durée de chaque signal ou bien, lorsque chaque signal est maintenu à un niveau donné non zéro pendant une certaine période, la durée de la période, étant choisie de sorte que la vitesse de la gouttelette éjectée de la dite buse en réponse au dit signal est sensiblement indépendante (a) de ce que les moyens électriquement excitables des canaux voisins du dit canal sont ou non excités de façon similaire pour effectuer une éjection de gouttelette simultanément à l'éjection de gouttelette de la dite buse, et (b) du nombre de gouttelettes à éjecter en fonction des données de ton d'impression.

2. Procédé selon la revendication 1, dans lequel des canaux successifs de la série sont régulièrement affectés à des groupes de sorte qu'un canal appartenant à un groupe quelconque est délimité de chaque côté par des canaux appartenant à au moins un autre groupe ;

   les groupes de canaux étant séquentiellement activés pour excitation dans des périodes successives ;

   la durée de chaque signal étant choisie de sorte que la vitesse d'une gouttelette, éjectée du dit canal en réponse au dit signal, est sensiblement indépendante (a) de ce que les canaux appartenant au même groupe que le dit canal et qui sont les plus proches du dit canal dans la série sont ou non excités de façon similaire pour effectuer une éjection de gouttelette simultanément à l'éjection de gouttelette du dit canal, et (b) du nombre de gouttelettes à éjecter en fonction des données de ton d'impression.

3. Procédé selon la revendication 1 ou 2, dans lequel le rapport de la durée de chaque signal à la demi-période d'oscillation des ondes de pression longitudinales dans le dit canal est compris dans les plages de 1,5 à 1,9 ou de 3,5 à 3,8 ou au voisinage des valeurs 5,5 et 7,5.

4. Procédé selon une quelconque des revendications précédentes, dans lequel les dits moyens électriquement excitables sont prévus pour faire varier le volume du dit canal, afin d'effectuer une éjection de gouttelette à partir de celui-ci.

5. Procédé selon la revendication 4, dans lequel le dit signal électrique effectue une expansion du dit canal suivie d'une contraction du dit canal.

6. Procédé selon la revendication 5, dans lequel le dit canal est maintenu dans des états d'expansion et de contraction pendant des durées égales.

7. Procédé selon la revendication 1, comprenant l'étape de :

   application d'une pluralité de signaux électriques aux moyens électriquement excitables associés au dit canal conformément aux données de ton d'impression, chaque signal électrique étant maintenu à un niveau donné non nul pendant une certaine période, la durée de la période étant choisie de sorte que la vitesse de la gouttelette éjectée du dit canal en réponse au dit signal est sensiblement indépendante (a) de ce que les canaux au voisinage du dit canal sont ou non excités de façon similaire pour effectuer une éjection de gouttelette simultanément à l'éjection de gouttelette à partir du dit canal, et (b) du nombre de gouttelettes à éjecter conformément aux données de ton d'impression.

8. Procédé selon la revendication 7, dans lequel les canaux successifs de la série sont régulièrement af-

fectés à des groupes de sorte qu'un canal appartenant à un groupe quelconque est délimité de chaque côté par des canaux appartenant à au moins un autre groupe ;

les groupes de canaux étant séquentiellement activés pour excitation dans des périodes successives ;

chaque signal électrique étant maintenu à un niveau donné non nul pendant une certaine période, la durée de la période étant choisie de sorte que la vitesse d'une gouttelette éjectée du dit canal en réponse au dit signal est sensiblement indépendante (a) de ce que les canaux qui appartiennent au même groupe que le dit canal et qui sont les plus proches du dit canal dans la série sont ou non excités de façon similaire pour effectuer une éjection de gouttelette simultanément à une éjection de gouttelette à partir du dit canal, et (b) du nombre de gouttelettes à éjecter conformément aux données de ton d'impression.

9. Procédé selon la revendication 7 ou 8, dans lequel le rapport de la durée de la période pendant laquelle chaque signal électrique est maintenu à un niveau donné non nul à la demi-période d'oscillation des ondes de pression longitudinales dans le dit canal se trouve dans les plages de 0,8 à 1,0 ou de 1,4 à 1,6.

10. Procédé selon une quelconque des revendications 7 à 9, dans lequel le signal électrique maintenu au dit niveau donné non nul crée une augmentation du volume du dit canal.

11. Procédé selon la revendication 10, dans lequel le dit signal électrique crée une expansion du dit canal suivie d'une contraction du dit canal.

12. Procédé selon la revendication 11, dans lequel le dit canal est maintenu dans un état d'expansion et un état de contraction pendant des durées égales.

13. Procédé selon une quelconque des revendications précédentes, dans lequel la dite pluralité de signaux électriques sont appliqués en succession immédiate.

14. Procédé selon une quelconque des revendications précédentes, dans lequel des signaux électriques successifs sont séparés dans le temps par une période de repos.

15. Procédé selon une quelconque des revendications précédentes, dans lequel un certain nombre d'autres signaux électriques sont appliqués aux moyens électriquement excitables, chaque autre signal provoquant un changement de température du fluide de formation de gouttelette dans le dit canal sans provoquer d'éjection de gouttelette, le dit changement de température étant sensiblement égal à celui qui est provoqué par l'application d'un signal électrique pour effectuer l'éjection d'une gouttelette.

16. Procédé selon la revendication 15, dans lequel les gouttelettes pour former un point imprimé sur le substrat sont éjectées dans une période d'éjection de gouttelettes, la somme du nombre de signaux électriques et du nombre de dits autres signaux électriques appliqués étant constante pour les périodes successives d'éjection de gouttelettes.

17. Procédé selon la revendication 15 ou 16, dans lequel le dit autre signal électrique est maintenu à un niveau donné non nul pendant une période supplémentaire.

18. Procédé selon la revendication 17, dans lequel le rapport de la durée de la dite période supplémentaire à la durée de la dite période pendant laquelle le dit signal électrique est maintenu à un niveau donné non nul est inférieur à 1.

19. Procédé selon la revendication 18, dans lequel le rapport est inférieur à 0,4.

20. Procédé selon la revendication 19, dans lequel le rapport est de 0,35 environ.

21. Procédé selon une quelconque des revendications 17 à 20, dans lequel le dit autre signal électrique est maintenu à un premier niveau donné non nul pendant une première période supplémentaire et ensuite à un deuxième niveau donné non nul pendant une deuxième période supplémentaire, les dits premier et deuxième niveaux donnés non nuls étant de signe opposé.

22. Procédé selon la revendication 21, dans lequel les dites première et deuxième périodes supplémentaires sont de durée égale.

23. Procédé selon une quelconque des revendications précédentes, dans lequel la vitesse de la gouttelette éjectée est au moins de 5 m/s et de préférence au moins de 7 m/s.

24. Procédé selon une quelconque des revendications précédentes, dans lequel la demi-période d'oscillation des ondes de pression longitudinales dans l'encre contenue dans le canal a une valeur n'excédant pas 5 µs et de préférence n'excédant pas 2,5 µs.

25. Tête d'impression à jet d'encre pour impression sur un substrat, la tête d'impression comprenant :

une série de canaux ;
une série de buses qui communiquent respectivement avec les dits canaux pour éjection de gouttelettes à partir de ceux-ci ;
des moyens de connexion pour connecter les canaux à une source d'encre ;
des moyens électriquement excitables associés à chaque canal et excitables une pluralité de fois en fonction de données de ton d'impression, afin d'éjecter un nombre correspondant de gouttelettes pour former un point imprimé de ton approprié sur le substrat ; et
un circuit de commande pour appliquer les signaux électriques une ou plusieurs fois aux moyens électriquement excitables associés à un canal, conformément aux données de ton d'impression ;

caractérisée en ce que le circuit de commande est configuré pour appliquer chaque signal électrique pendant une durée choisie, ou pour maintenir chaque signal à un niveau donné non nul pendant une période, la durée de la période étant choisie, de sorte que la vitesse de la gouttelette éjectée de la dite buse en réponse au dit signal est sensiblement indépendante (a) de ce que les moyens électriquement excitables des canaux au voisinage du dit canal sont ou non excités de façon similaire pour effectuer une éjection de goutte simultanément à l'éjection de goutte de la dite buse, et (b) du nombre de gouttelettes à éjecter en fonction des données de ton d'impression.

26. Circuit de commande pour une tête d'impression à jet d'encre pour imprimer sur un substrat, la tête d'impression comprenant :

une série de canaux ;
une série de buses qui communiquent respectivement avec les dits canaux pour éjection de gouttelettes à partir de ceux-ci ;
des moyens de connexion pour connecter les canaux à une source d'encre ; et
des moyens électriquement excitables associés à chaque canal et excitables une pluralité de fois conformément à des données de ton d'impression, afin d'éjecter un nombre correspondant de gouttelettes pour former un point imprimé de ton approprié sur le substrat ;
le dit circuit de commande étant configuré pour appliquer les signaux électriques une ou plusieurs fois aux moyens électriquement excitables associés à un canal conformément aux données de ton d'impression ;

caractérisé en ce que le circuit de commande est configuré pour appliquer chaque signal électrique pendant une durée choisie, ou bien pour maintenir chaque signal à un niveau donné non nul pendant une certaine période, la durée de la période étant choisie, de sorte que la vitesse de la gouttelette éjectée de la dite buse en réponse au dit signal est sensiblement indépendante (a) de ce que les moyens électriquement excitables des canaux situés au voisinage du dit canal sont ou non excités de façon similaire pour effectuer une éjection de goutte simultanément à l'éjection de goutte à partir de la dite buse, et (b) du nombre de gouttelettes à éjecter conformément aux données de ton d'impression.

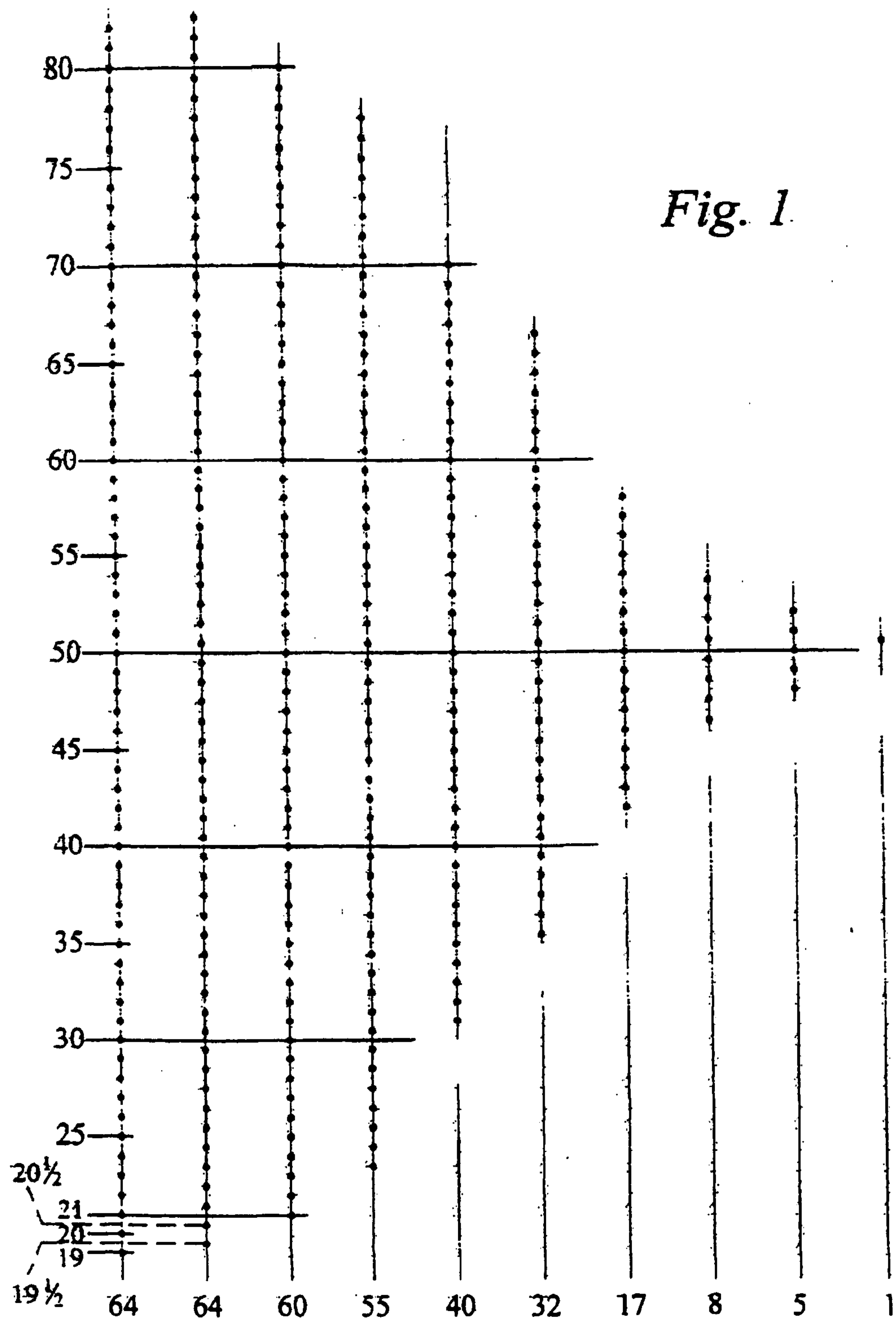

80
75
70
65
60
55
50
45
40
35
30
25
20½
21
20
19
19½
64
64
60
55
40
32
17
8
5
1

Fig. 1

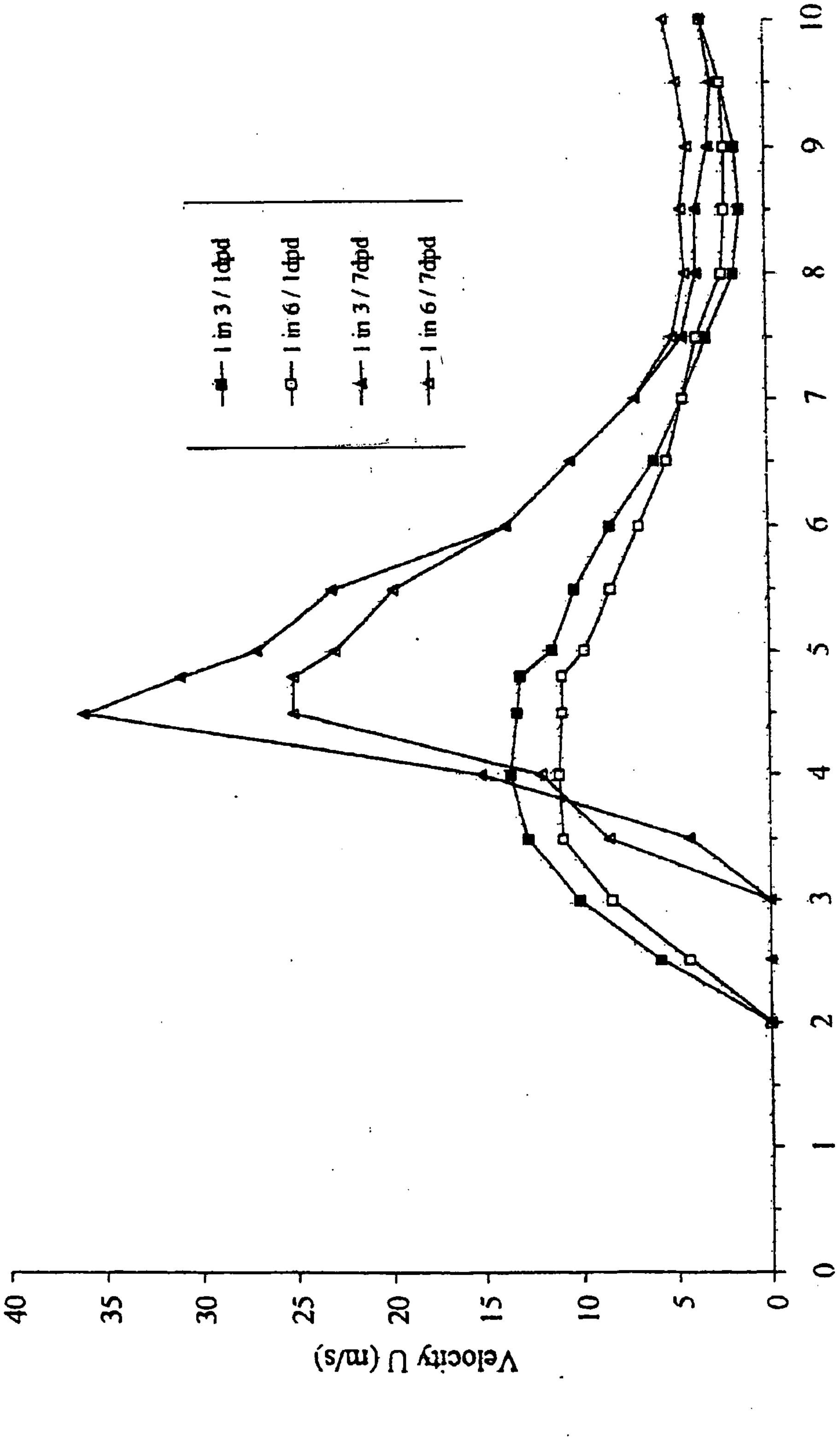

1 in 3 / 1dpd
1 in 6 / 1dpd
1 in 3 / 7dpd
1 in 6 / 7dpd
Velocity U (m/s)
T (µs)
0
5
10
15
20
25
30
35
40
0
1
2
3
4
5
6
7
8
9
10

Fig. 2

Fig. 3A

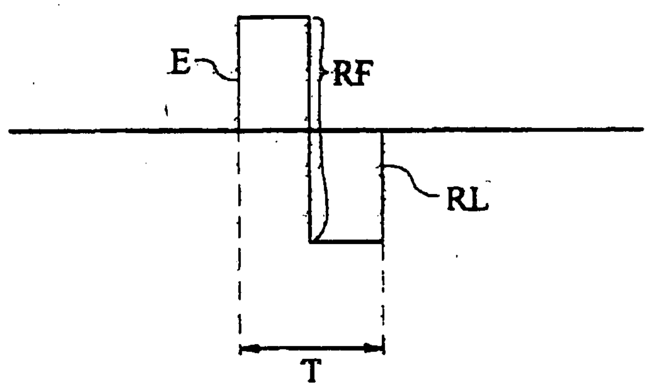
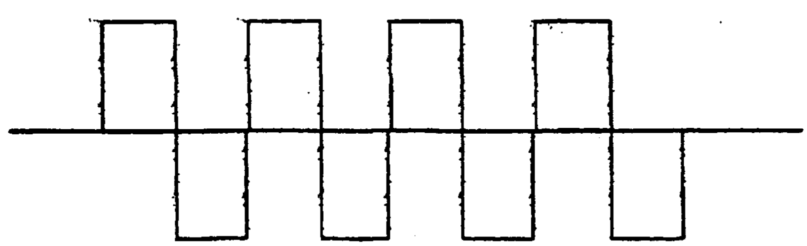


Fig. 3B



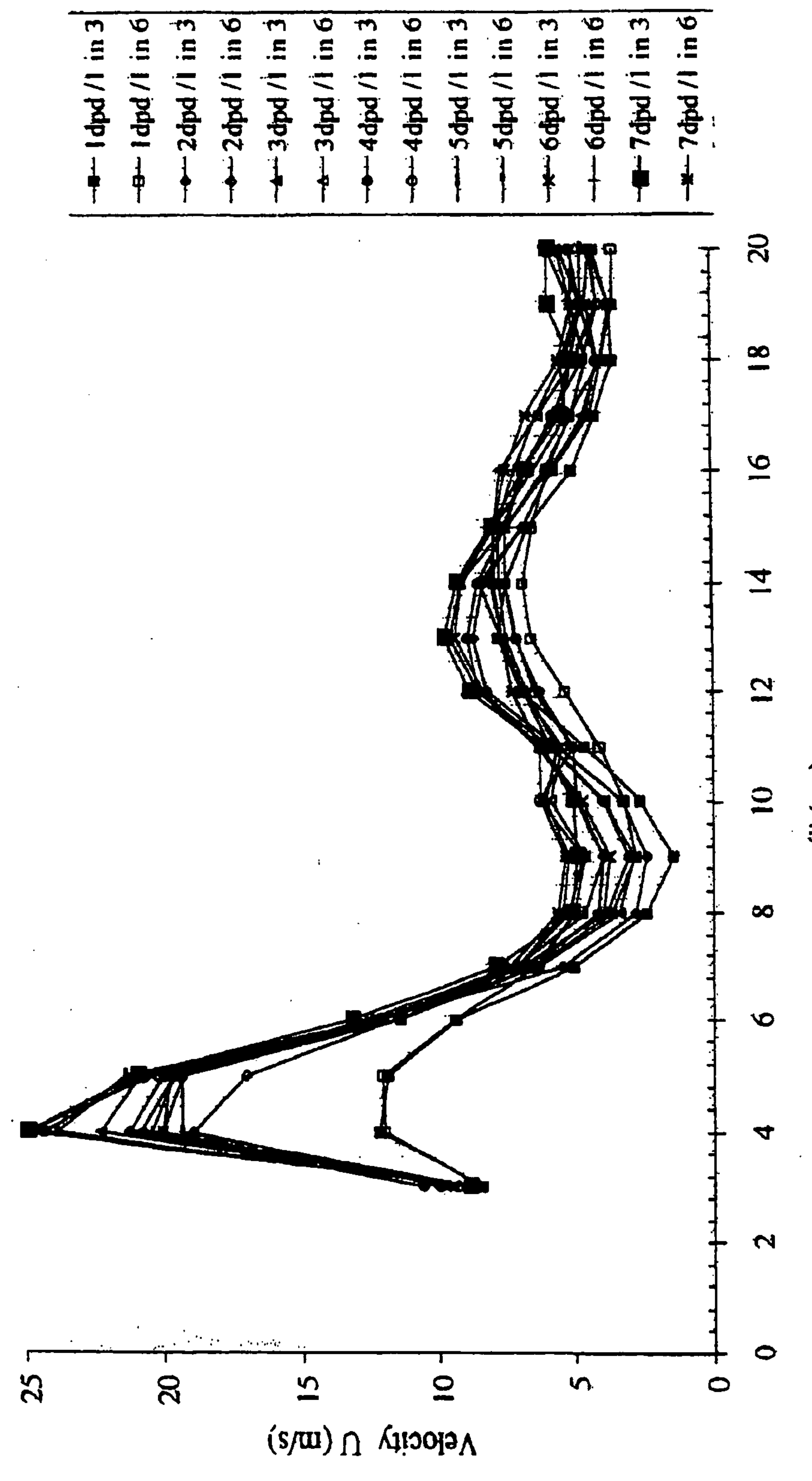
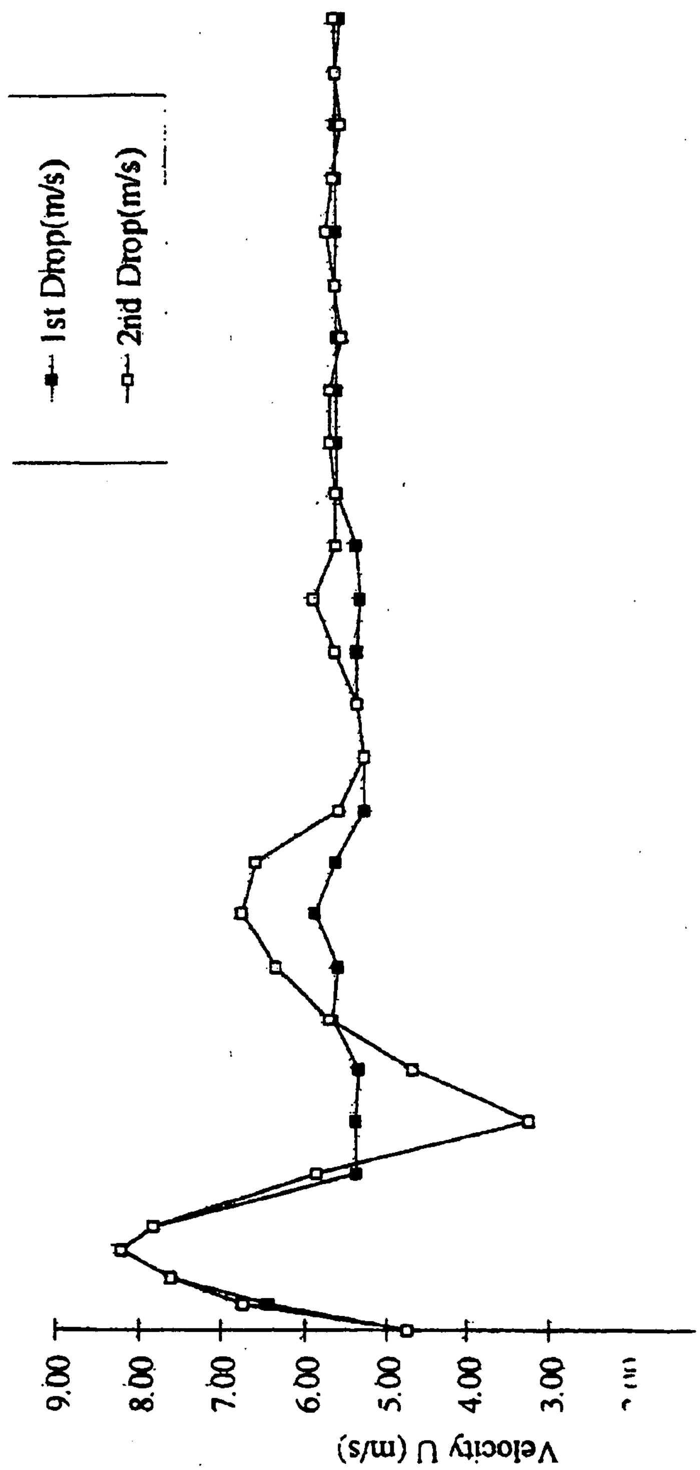

1dpd/l in 3
1dpd/l in 6
2dpd/l in 3
2dpd/l in 6
3dpd/l in 3
3dpd/l in 6
4dpd/l in 3
4dpd/l in 6
5dpd/l in 3
5dpd/l in 6
6dpd/l in 3
6dpd/l in 6
7dpd/l in 3
7dpd/l in 6
Velocity U (m/s)
T (µs)
0
5
10
15
20
25
0
2
4
6
8
10
12
14
16
18
20

Fig. 4


1st Drop(m/s)
2nd Drop(m/s)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
Velocity U (m/s)

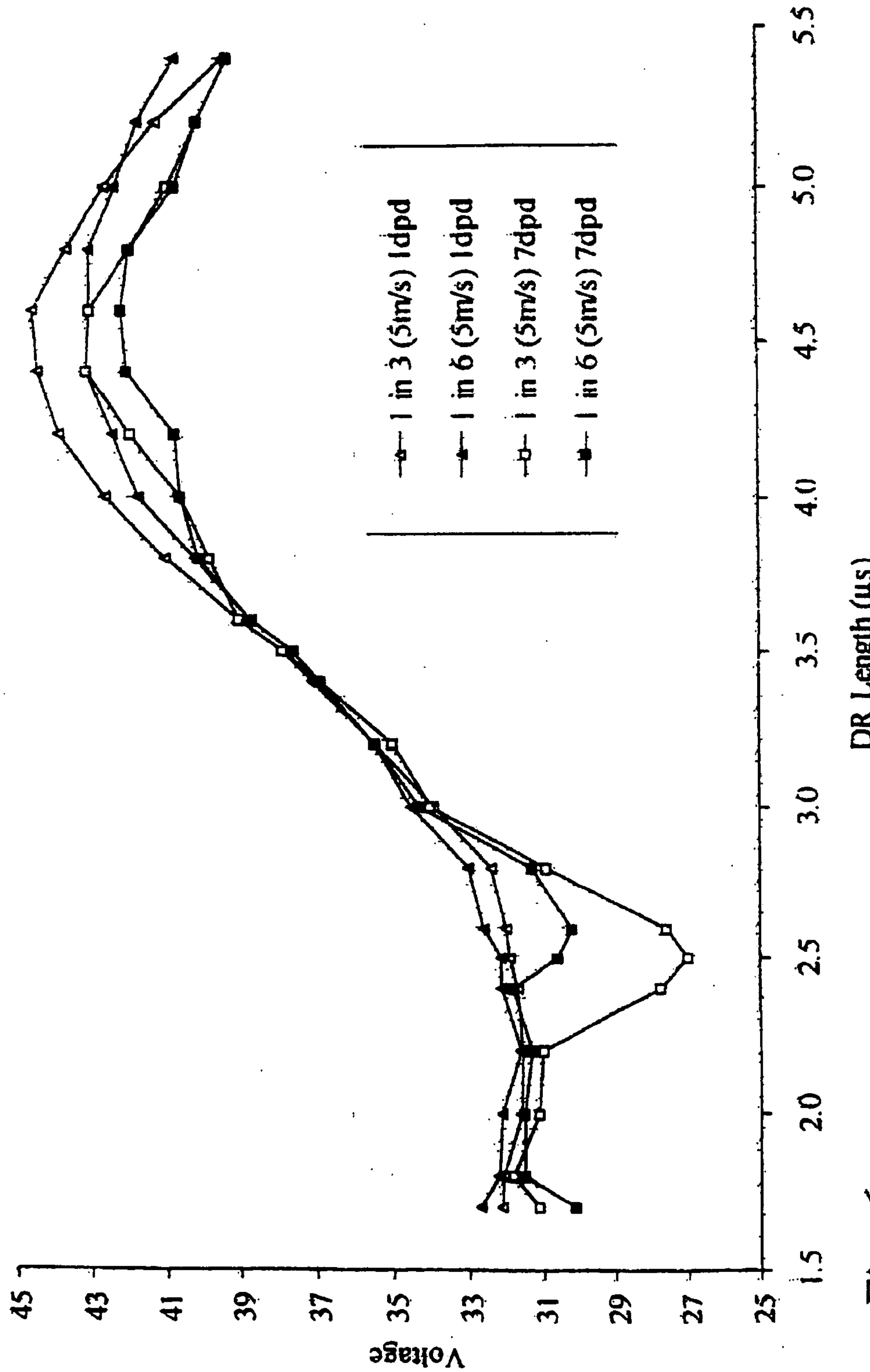
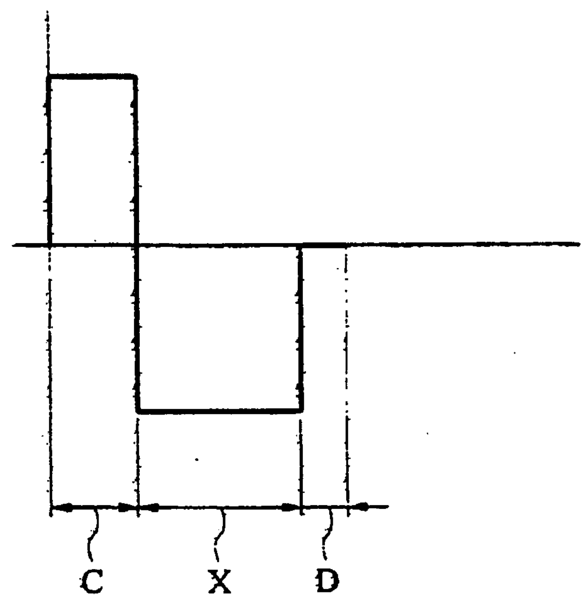

Voltage
45
43
41
39
37
35
33
31
29
27
25
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
DR Length (µs)
1 in 3 (5m/s) 1dpd
1 in 6 (5m/s) 1dpd
1 in 3 (5m/s) 7dpd
1 in 6 (5m/s) 7dpd

Fig. 6

Fig. 7



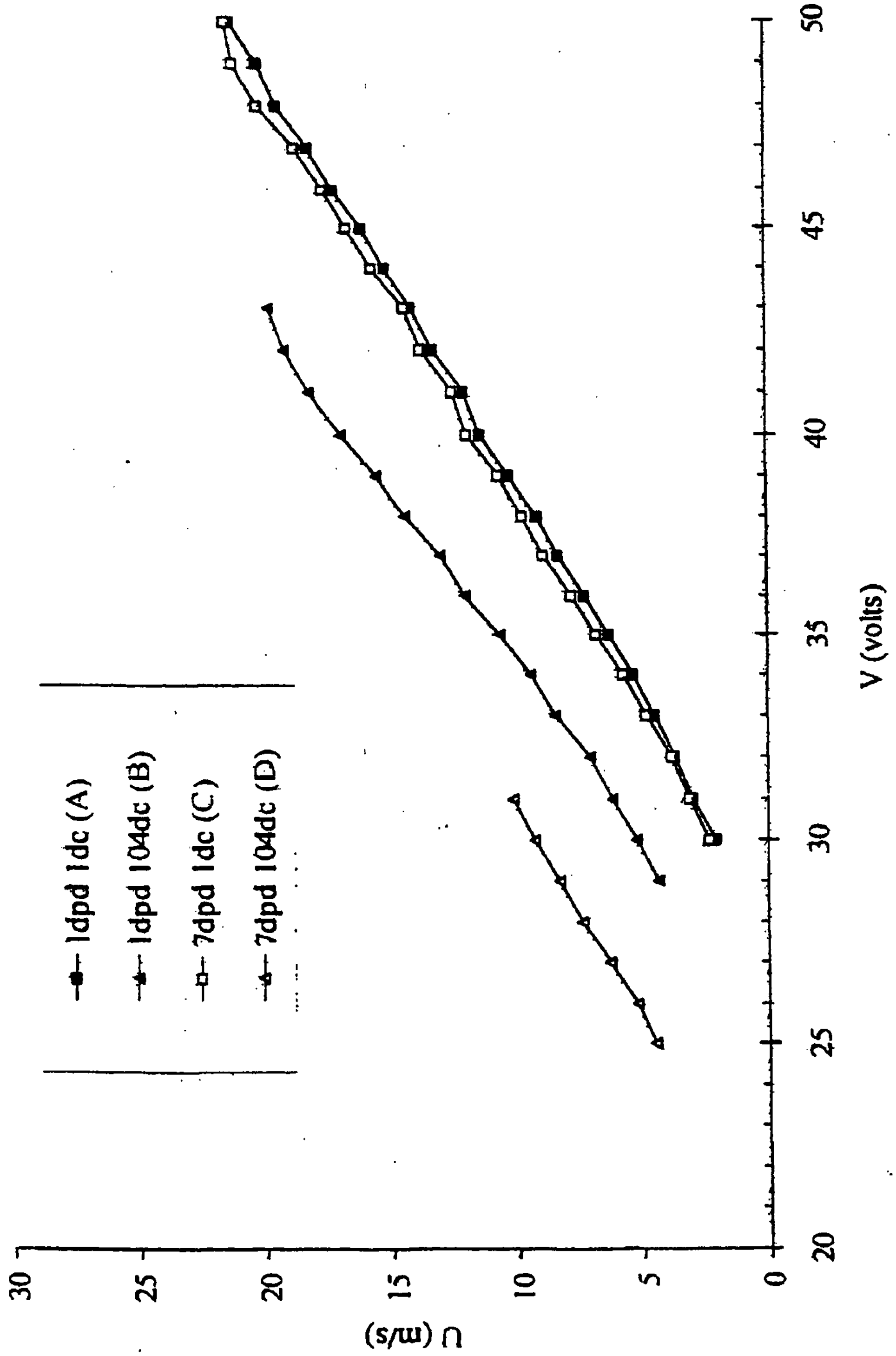
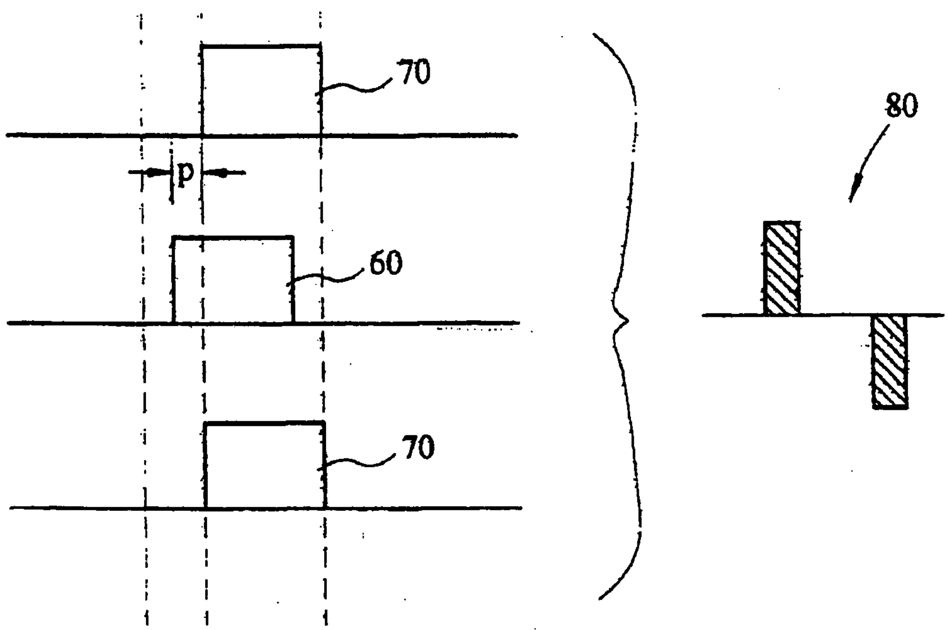

1dpd 1dc (A)
1dpd 104dc (B)
7dpd 1dc (C)
7dpd 104dc (D)
U (m/s)
V (volts)
0
5
10
15
20
25
30
20
25
30
35
40
45
50

Fig. 8

Fig. 9



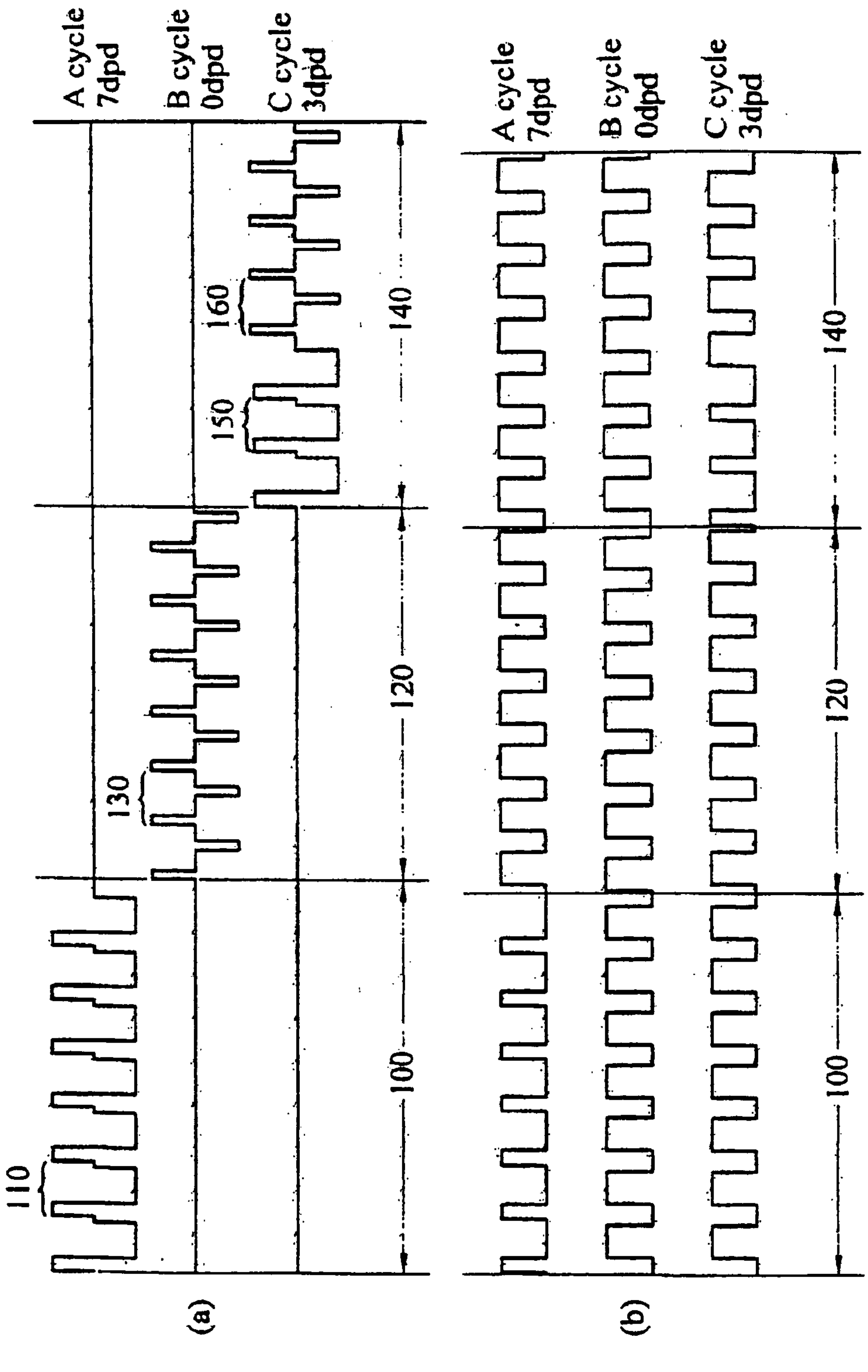

A cycle
7dpd
B cycle
0dpd
C cycle
3dpd
110
130
150
160
100
120
140
(a)
A cycle
7dpd
B cycle
0dpd
C cycle
3dpd
100
120
140
(b)

Fig. 10

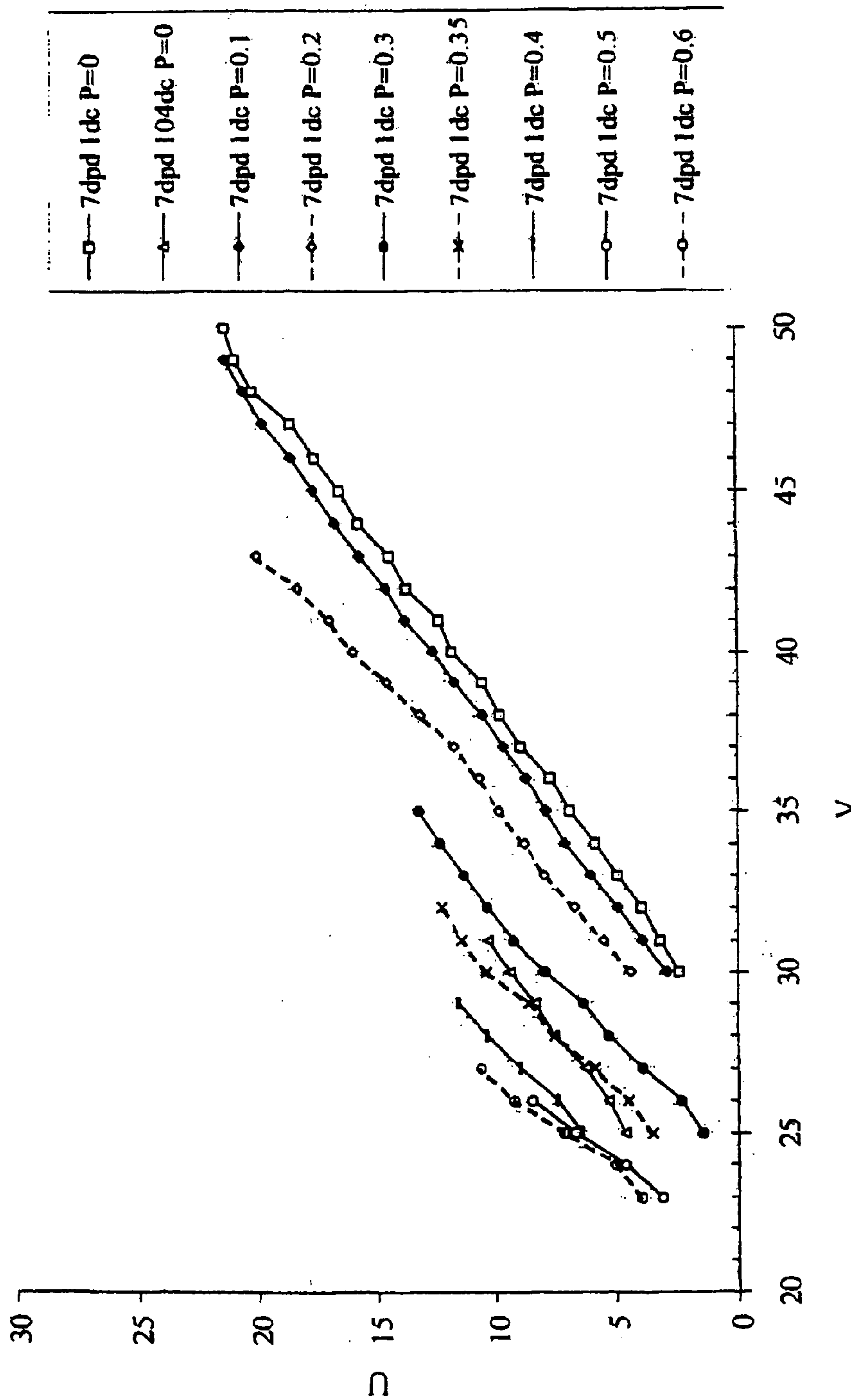

7dpd 1dc P=0
7dpd 104dc P=0
7dpd 1dc P=0.1
7dpd 1dc P=0.2
7dpd 1dc P=0.3
7dpd 1dc P=0.35
7dpd 1dc P=0.4
7dpd 1dc P=0.5
7dpd 1dc P=0.6
U
V
0
5
10
15
20
25
30
20
25
30
35
40
45
50

Fig. 11

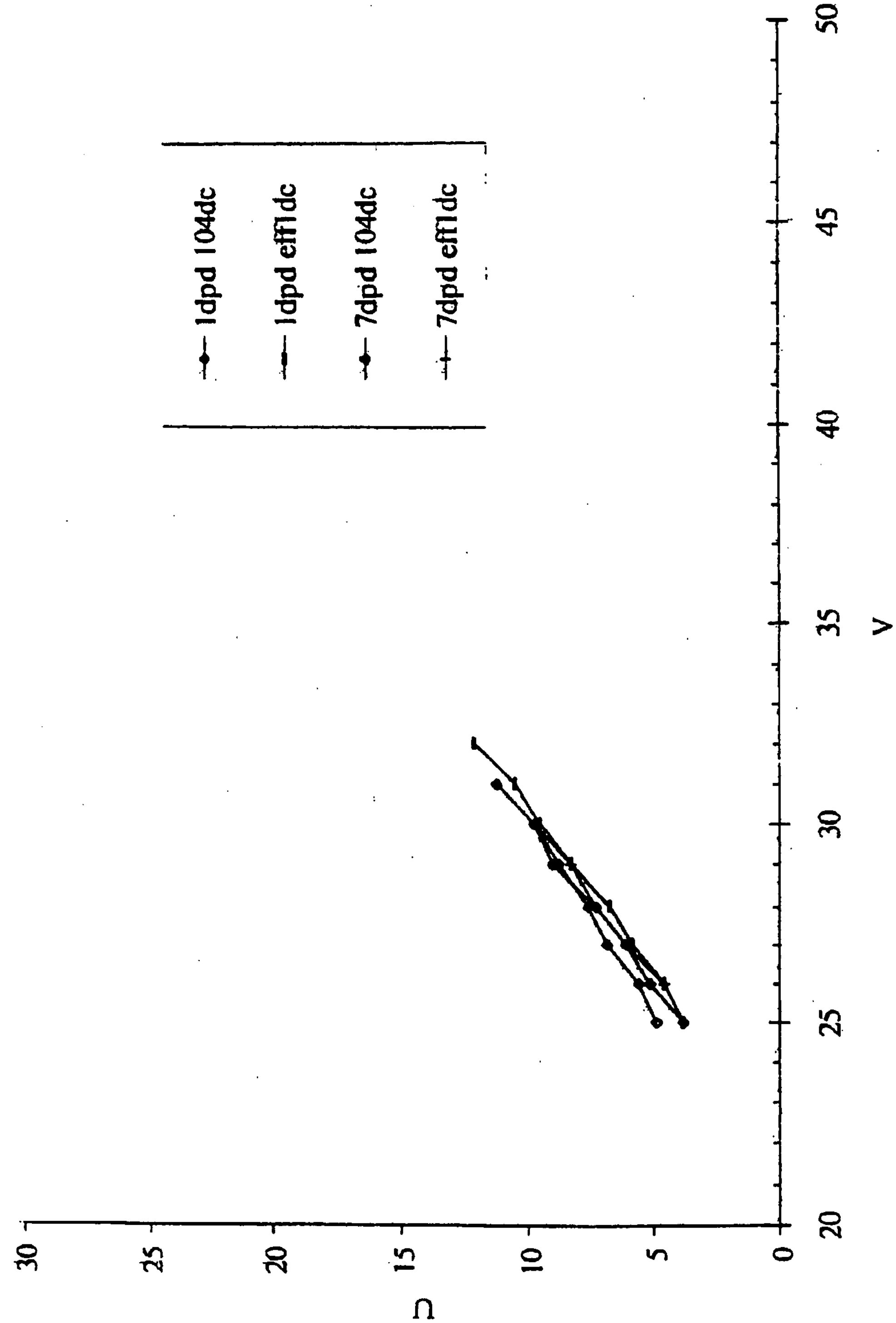

1dpd 104dc
1dpd eff1dc
7dpd 104dc
7dpd eff1dc
U
V
0
5
10
15
20
25
30
20
25
30
35
40
45
50

Fig. 12

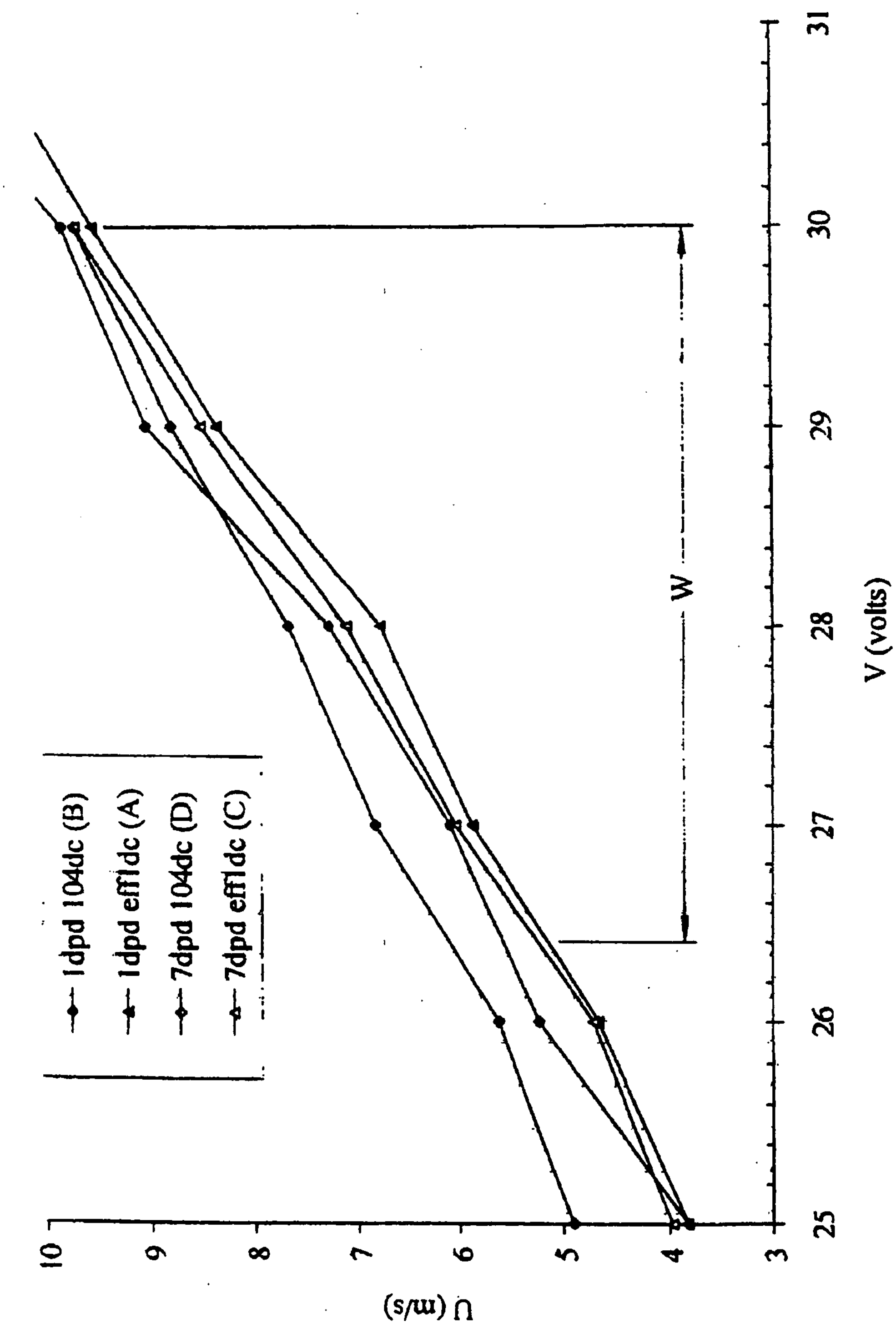

1dpd 104dc (B)
1dpd eff1dc (A)
7dpd 104dc (D)
7dpd eff1dc (C)
W
U (m/s)
V (volts)
3
4
5
6
7
8
9
10
25
26
27
28
29
30
31

Fig. 13